

CLAIMS

We claim:

1. A tungsten-containing fuel cell catalyst comprising a carbon support having a surface layer containing tungsten, the tungsten-containing catalyst generating a power output which is greater than about 20 percent of a power output of an equivalently prepared platinum catalyst when operating under the same conditions using an electrochemical oxidation of hydrogen.
2. The tungsten-containing catalyst of claim 1 wherein the power output of the tungsten-containing catalyst is greater than about 40% of the power output of the platinum catalyst.
3. The tungsten-containing catalyst of claim 1 wherein the power output of the tungsten-containing catalyst is greater than about 80% of the power output of the platinum catalyst.
4. The tungsten-containing catalyst of claim 1 wherein the power output of the tungsten-containing catalyst is about 100% of the power output of the platinum catalyst.
5. A tungsten-containing fuel cell catalyst comprising a carbon support having a surface layer containing tungsten, the tungsten-containing catalyst in a hydrogen:air PEM fuel cell having a single 5 cm<sup>2</sup> cell producing a cell voltage of about 0.75 volts at a 1000 ohm load.
6. A tungsten-containing fuel cell catalyst comprising a carbon support having a surface layer containing tungsten, the

tungsten-containing catalyst producing a potential of about 0.25 volts at current densities of between about 2 to about 6 mA/cm<sup>2</sup> at a temperature of about 25°C and a pressure of about 1 atmosphere.

7. The tungsten-containing catalyst of claim 6 wherein the potential is measured in a hydrogen:air fuel cell having an anode made with the tungsten-containing catalyst and a cathode made with a platinum catalyst.

8. The tungsten-containing catalyst of claim 1 wherein the tungsten-containing catalyst has a tungsten loading of about 20 weight percent tungsten.

9. The tungsten-containing catalyst of claim 1 wherein the tungsten-containing catalyst has a tungsten loading of about 40 weight percent tungsten.

10. A method of making a tungsten-containing fuel cell catalyst comprising the steps of:

(a) depositing a tungsten-containing precursor on a carbon support;

(b) contacting the support with a solution of an electrolyte;

(c) applying a voltage to the support sufficient to form the tungsten-containing catalyst.

11. The method of claim 10 wherein the electrolyte solution contains a fluid-based carbon source.

12. The method of claim 11 wherein the fluid-based carbon source is an alcohol, an aqueous carbonate, an organic acid solution, or bubbled CO or CO<sub>2</sub> gas.
13. The method of claim 10 wherein the electrolyte is 2M Na<sub>2</sub>CO<sub>3</sub>.
14. The method of claim 10 wherein the applied voltage is about 0.5 VDC to about 30 VDC.
15. The method of claim 13 wherein the applied voltage is 4 VDC.
16. The method of claim 10 wherein the tungsten-containing precursor is ammonium tungstate, sodium tungstate, tungstic acid or a tungsten heteropoly salt.
17. The method of claim 10 wherein the tungsten-containing precursor is ammonium metatungstate.
18. The method of claim 17 wherein the electrolyte solution contains a fluid-based carbon source.
19. The method of claim 17 wherein the fluid-based carbon source is an alcohol, an aqueous carbonate, an organic acid solution, or bubbled CO or CO<sub>2</sub> gas.
20. The method of claim 17 wherein the electrolyte solution is 2M Na<sub>2</sub>CO<sub>3</sub>.
21. The method of claim 10 wherein the carbon support is a carbon black which has been pretreated with a cationic surfactant.

22. The method of claim 21 wherein the cationic surfactant is cetylpyridinium chloride.

23. A method of making a tungsten-containing fuel cell catalyst comprising the steps of:

(a) mixing a carbon black with a solution of a tungsten-containing precursor to form a dispersion;

(b) drying the dispersion to form a supported catalyst precursor;

(c) forming an anode electrode using the supported catalyst precursor;

(d) contacting the catalyst precursor with a solution of an electrolyte; and

(e) applying a voltage to the anode sufficient to form the tungsten-containing catalyst.

24. The method of claim 23 wherein the tungsten-containing precursor is ammonium tungstate, sodium tungstate, tungstic acid, or a tungsten heteropoly salt.

25. The method of claim 23 wherein the electrolyte contains a fluid-based carbon source.

26. The method of claim 25 wherein the fluid-based carbon source is an alcohol, an aqueous carbonate, an organic acid solution, or bubbled CO or CO<sub>2</sub> gas.

27. The method of claim 24 wherein the tungsten-containing precursor is ammonium metatungstate and the electrolyte solution is 2M Na<sub>2</sub>CO<sub>3</sub>.

28. The method of claim 23 wherein the tungsten-containing catalyst is formed in situ in a proton-exchange membrane fuel cell.

29. The method of claim 28 wherein the applied voltage is from about 0.5 VDC to about 30 VDC.

30. The method of claim 29 wherein the tungsten-containing precursor is ammonium metatungstate and the electrolyte solution is 2M  $\text{Na}_2\text{CO}_3$ .

31. The method of claim 30 wherein the applied voltage is 4 VDC.

32. The method of claim 23 wherein the carbon black has been pretreated with a cationic surfactant.

33. The method of claim 32 wherein the cationic surfactant is cetylpyridinium chloride.

34. A method of regenerating a tungsten-containing fuel cell catalyst comprising the steps of:

a) contacting the catalyst with a fluid-based carbon source;

b) applying a voltage to the catalyst sufficient to substantially regenerate the catalyst.

35. The method of claim 34 wherein the catalyst is first contacted with a dilute tungstate solution.

36. The method of claim 34 wherein the applied voltage is from about 0.5 VDC to about 30 VDC.

37. The method of claim 34 wherein the regeneration is performed in situ in a fuel cell.

38. The method of claim 34 wherein the fluid-based carbon source is an aqueous solution of sodium carbonate.

39. The method of claim 35 wherein the dilute tungstate solution is a solution of ammonium metatungstate.